Towards PIV assimilation of large-scale wake flows: study of several sub-grid models

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ABSTRACT

With the increasing attraction of data assimilation combined with improved computational power, the concept of using image based velocity measurements as a guiding mechanism for the numerical simulation of flow dynamics has gained a lot of interest. Previous PIV Data Assimilation study implemented on Incompact3d -a parallelised flow solver developed by [1]- has performed admirably in the case of a DNS of low Reynolds number wake flow [2]. However, performing such data assimilation on a Direct Numerical Simulation (DNS) basis remains computationally unachievable even for flows at moderate Reynolds number. Only, coarse Large Eddy Simulation (LES) is conceivable. This necessitates the identification of the best suited subgrid model for the flow under study, i.e. cylinder wake flow at a Reynolds number of 3900 corresponding to the turbulent Von-Karman vortex shedding regime (see figure 1 left). This is the focus of the present work.

Over the past decades, numerous LES sub-grid scale (SGS) models have been proposed each possessing some unique set of advantages. However, there exists no universal model providing statistically accurate results for all types of flows. Several SGS models have been compared. Models under scrutiny include the classical Smagorinsky model along with contemporary models under uncertainty developed by [2] namely Stochastic Smagorinsky (StSmag), Stochastic Spatial (StSp), and Stochastic Temporal (StTe) covariance models. The numerical simulation was performed on a very low-resolution mesh compared to a DNS as well as the LES simulations of [3]. The simulation statistics have been compared with the PIV data of [3] along with an under resolved DNS (URDNS) at the LES resolution mainly to identify the improvements in statistics (see figure 1 right). The statistics clearly show improved fit to the PIV data with the stochastic SGS models as compared to classic Smagorinsky model that over smoothens the velocity gradient– the directional dissipation associated with the stochastic models along with other factors can be attributed to this improvement. The next step will consist to perform a 4DVar PIV assimilation with such SGS models.

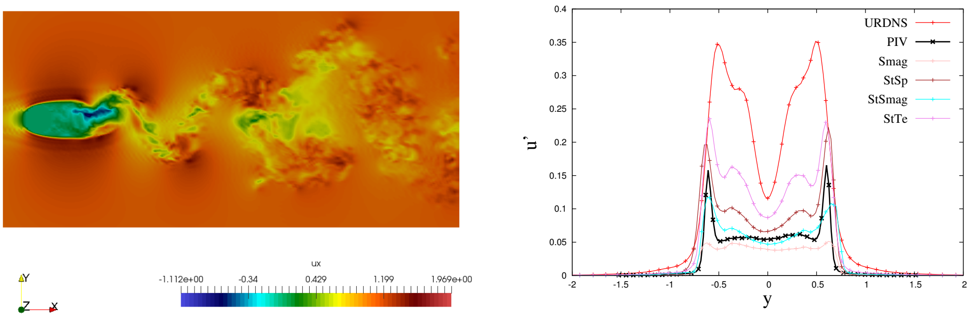

Figure 1 Cylinder wake flow LES simulations based on location uncertainty principle: (Left), Velocity norm for the LES with the StSP subgrid tensor; (Right), Streamwise velocity fluctuation profiles at 1.06D behind the cylinder axis, for different subgrid tensor models compared with PIV of [3] and an under resolved DNS.

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